What is claimed is:

1. In a fuel conversion reactor, a shell-and-tube heat exchanger for heating a gaseous fluid prior to reaction with a fuel and for cooling a gaseous mixture produced by the reaction, said heat exchanger comprising:

a primary shell member having primary and secondary ends and a sidewall extending between said ends and defining a heat exchanging chamber located within the shell member;

an inlet for introducing said gaseous fluid into said heat exchanging chamber;

a first tube sheet fixedly mounted on said primary shell member in the vicinity of said primary end and sealingly closing said heat exchanging chamber at one end of the chamber;

a second tube sheet device which is separate from said primary shell member and is located in the vicinity of said secondary end, said second tube sheet device forming another end of said chamber that is opposite said one end of the chamber; and

a plurality of heat exchange tubes extending from said first tube sheet to said second tube sheet device and rigidly connected to both the first tube sheet and the second tube sheet device, said heat exchange tubes providing passageways for said gaseous mixture to flow inside the tubes through said heat exchanging chamber;

wherein one or more outlet apertures are formed in the region of said secondary end of said primary shell member in order to provide at least one outlet for said gaseous fluid which flows through said heat exchanging chamber on a shell-side thereof during operation of said fuel conversion reactor.

2. A fuel conversion reactor according to claim 1, wherein said one or more outlet apertures are formed in at least one of said primary shell member and said second tube sheet device.

3. A fuel conversion reactor according to claim 1, wherein said one or

more outlet apertures are formed between said primary shell member and said second tube sheet device.

4. A fuel conversion reactor according to any one of claims 1 to 3 including an outer shell having first and second ends and an outer shell wall extending between said first and second ends, said outer shell being closed at said second end, extending around said primary shell member and said second tube sheet device, and having an inlet for said fuel, wherein a fuel passageway is formed between said outer shell wall and said sidewall of the primary shell member and extends from said inlet for the fuel to said one or more outlet apertures.

5. A fuel conversion reactor according to claim 4 wherein said second tube sheet device includes a secondary shell member having a peripheral sidewall with an end of the secondary shell member located adjacent said secondary end of the primary shell member and, together with said secondary end, forming a disconnected joint, and wherein said second tube sheet device is free to move relative to said primary shell member upon thermal expansion of said heat exchange tubes.

6. A fuel conversion reactor according to claim 5 wherein a gap is formed at said disconnected joint.

7. A fuel conversion reactor according to claim 6, wherein said one or more outlet apertures comprises said gap.

8. A fuel conversion reactor according to claim 1, further comprising a first catalyst to catalyze the reaction of the fuel and the gaseous fluid, said catalyst being mounted in a secondary shell member having a peripheral sidewall, with an end of said peripheral sidewall being located adjacent said secondary end of the primary shell member and, together with said secondary end, forming a disconnected joint, said catalyst being arranged for flow of a mixture of said fuel and said gaseous fluid therethrough to produce said gaseous mixture.

9. A fuel conversion reactor according to claim 8, wherein the first catalyst comprises an autothermal reformation catalyst.

10. A fuel conversion reactor according to claim 8, wherein the first catalyst comprises a partial oxidation catalyst.

11. A fuel conversion reactor according to claim 8, wherein the first catalyst comprises a steam reformation catalyst.

12. A fuel conversion reactor according to claim 8, wherein the first catalyst comprises a combustion catalyst.

13. A fuel conversion reactor according to claim 8, further comprising a second catalyst arranged in said primary shell member in the vicinity of said primary end and outside said heat exchanging chamber.

14. A fuel conversion reactor according to claim 13, wherein the second catalyst is a water/gas shift reaction catalyst.

15. A fuel conversion reactor according to claim 13, wherein the second catalyst is a preferential oxidation catalyst.

16. A fuel conversion reactor according to claim 1, wherein said one or more outlet apertures are formed at said secondary end of said primary shell member.

17. A fuel conversion reactor according to claim 1, wherein said second tube sheet device includes a secondary shell member having a peripheral sidewall with a first predetermined diameter and a coaxial sleeve extension extending from said peripheral sidewall at an end thereof closest to said secondary end and having a second predetermined diameter different than said first predetermined diameter, wherein said sleeve extension has a free end located in the region of said one or more outlet apertures which are

formed at or near said secondary end of said primary shell member, and wherein said secondary shell member is relatively movable during use of said fuel conversion reactor between a first position wherein said one or more apertures are partially blocked by said sleeve extension and a second position where said one or more apertures are at least substantially open for passage of said gaseous fluid.

18. A fuel conversion reactor according to claim 1, wherein said second tube sheet device includes a secondary shell member having a peripheral sidewall with a first internal diameter, said primary shell member has a primary external diameter and a coaxial sleeve extension extending from its sidewall at its secondary end, said sleeve extension having an external diameter different from said primary external diameter and different from said first internal diameter and having a free end located in the region of said one or more outlet apertures which are formed around said second tube sheet device, and wherein said secondary shell member is relatively movable during use of said fuel conversion reactor between a first position wherein said one or more apertures are partially blocked by said sleeve extension and a second position where said one or more apertures are at least substantially open for passage of said gaseous fluid.

19. A heat exchanging apparatus for a fuel conversion reactor, said heat exchanging apparatus comprising:

an outer shell having first and second ends and inner and external surfaces extending between said first and second ends, said second end being closed;

a first inlet for a fuel provided in said outer shell in the vicinity of said first end;

a primary inner shell having primary and secondary ends and an outer surface extending between said primary and secondary ends, said primary inner shell extending into said outer shell and being joined thereto;

a fuel passageway formed between said outer surface of said inner shell and said inner surface of said outer shell and extending longitudinally from said first inlet to said secondary end of said inner shell;

a secondary inner shell having a first end located adjacent said secondary end of said primary inner shell and a second end spaced from the first end of the secondary inner shell;

one or more outlet apertures being formed in at least one of said primary inner shell and said secondary inner shell in the region of said secondary end of said primary inner shell in order to provide for passage of a gaseous fluid out of said primary inner shell;

a further passageway formed between said secondary inner shell and said outer shell and extending from said first end to said second end of the secondary inner shell, a mixture of said fuel and said gaseous fluid flowing through said further passageway during use of said apparatus;

a first tube sheet fixedly mounted in said primary inner shell in proximity to said primary end and sealingly closing off said primary inner shell;

a second tube sheet fixedly connected to said secondary inner shell and sealingly closing off said secondary inner shell; and

a plurality of heat exchange tubes extending from said first tube sheet to said second tube sheet and connected to both tube sheets, said heat exchange tubes forming passageways for a hot gaseous mixture to flow through said second tube sheet and then through said first tube sheet, said hot gaseous mixture being cooled in said tubes during use of said apparatus.

20. A heat exchanging apparatus according to claim 19 wherein said secondary end of said primary inner shell and said first end of said secondary inner shell form a disconnected joint and said secondary inner shell is free to move relative to said primary inner shell upon thermal expansion of said heat exchange tubes.

21. A heat exchanging apparatus according to claim 19 including a second inlet for said gaseous fluid provided in a side of said primary inner shell in the vicinity of said primary end.

22. A heat exchanging apparatus according to claim 19, wherein baffle plates are mounted within said primary inner shell between said first and second tube sheets.

23. A heat exchanging apparatus according to claim 19, wherein said one or more outlet apertures can vary in effective size during use of said heat exchanging apparatus.

24. A heat exchanging apparatus according to claim 19, wherein said outer shell is formed with projections that are spaced around the outer shell and that project inwardly to engage said outer surface of the primary inner shell.

25. A heat exchanging apparatus according to claim 19, wherein a catalyst can be mounted within said outer shell in the region of said second end and arranged for effective contact with said mixture of said fuel and said gaseous fluid in order to produce said hot gaseous mixture.

26. A heat exchanging apparatus according to claim 25 including said catalyst, which is a catalyst for a fuel conversion reaction of a hydrogen-containing fuel to produce a hot gaseous mixture containing hydrogen, said catalyst being mounted within said outer shell in the region of said second end and able to produce said hot gaseous mixture by effective contact with said mixture of said fuel and said gaseous fluid.

27. A heat exchanging apparatus according to claim 26, wherein said hot gaseous mixture is a hydrogen-containing reformate having a temperature of at least 500°C.

28. A heat exchanging apparatus according to claim 25 including said catalyst, which is a catalyst for an autothermal reformation of a hydrogen-containing fuel to produce a hot gaseous mixture containing hydrogen, mounted within said outer shell in the region of said second end and able to produce said hot gaseous mixture by effective contact with said mixture of said fuel and said gaseous fluid.

29. A heat exchanging apparatus according to any one of claims 25 to 28, wherein said primary inner shell has a catalyst containing section adjacent

said primary end thereof, a further catalyst is mounted in said catalyst containing section, and said primary inner shell has an outlet so as to allow outflow of a hydrogen-containing reformate therefrom.

30. A heat exchanging apparatus according to claim 29, wherein said further catalyst comprises a catalyst for a carbon monoxide cleanup reaction operatively connected to a downstream end of said passageways formed by said heat exchange tubes, said carbon monoxide cleanup catalyst being selected from the group comprising a water/gas shift reaction catalyst and a preferential oxidation catalyst.

31. A fuel reformer for converting hydrogen-containing fuel to hydrogen using a catalytic reaction, said reformer comprising:

a primary shell member having primary and secondary ends and a sidewall extending between said ends;

a secondary shell member having a first end located adjacent said secondary end of the primary shell member, one or more outlet apertures being formed in at least one of said primary shell member and said secondary shell member in the region of said secondary end of said primary shell member in order to provide at least one outlet for a gaseous fluid flowing through said primary shell member;

an inlet located on said primary shell member and provided for introduction of said gaseous fluid into a heat exchanging chamber formed by said primary shell member;

a first tube sheet fixedly mounted on said primary shell member and sealingly closing said heat exchanging chamber at a first end of the chamber;

a second tube sheet fixedly connected to said secondary shell member and forming a second end of said heat exchanging chamber which is opposite said first end;

a plurality of heat exchange tubes extending from said first tube sheet to said second tube sheet and rigidly connected to both tube sheets, said heat exchange tubes providing passageways for a hot gaseous mixture to flow through said heat exchanging chamber to a downstream end of said passageways;

a first catalyst for a fuel conversion reaction located adjacent said second tube sheet and outside said heat exchanging chamber and adapted to produce said hot gaseous mixture from a mixture of said hydrogen-containing fuel and said gaseous fluid, said hot gaseous mixture being cooled to a desired temperature by heat exchange with the gaseous fluid passing through said heat exchanging chamber during use of the reformer;

a second catalyst for a second catalytic reaction arranged outside said heat exchanging chamber and operatively connected to said downstream end of said passageways so that the cooled gaseous mixture is brought into effective contact with said second catalyst during use of said reformer; and

a hydrogen-containing fuel mixture delivery arrangement adapted to deliver said mixture of said hydrogen-containing fuel and said gaseous fluid, the latter flowing from said one or more outlet apertures, to said first catalyst.

32. A fuel reformer according to claim 31, wherein said gaseous fluid is a mixture of steam and air and said delivery arrangement comprises an outer shell member extending around said primary and secondary shell members and rigidly connected to said primary shell member.

33. A fuel reformer according to claim 31 or 32, wherein said first end of said secondary shell member and said secondary end of said primary shell member form a disconnected joint and the size of said at least one outlet varies and is dependent on operating temperatures of the fuel reformer in said heat exchanging chamber.

34. A fuel reformer according to claim 32, wherein a hydrogen-containing fuel inlet is provided at one end of said outer shell member located closest to said primary end and fuel passageways are formed between said outer shell member and said primary shell member and extend from said fuel inlet to said one or more outlet apertures.

35. A fuel reformer according to claim 34, wherein one or more further passageways are formed between said outer shell member and said secondary shell member, said further passageways allowing said mixture of

said hydrogen-containing fuel and said gaseous fluid to flow from a region adjacent said one or more outlet apertures to an enclosed mixing chamber adjacent said first catalyst.

36. A fuel reformer according to any one of claims 31 to 35 including one or more baffle plates mounted on said heat exchange tubes and located within said heat exchanging chamber, said one or more baffle plates in use causing the flow of said gaseous fluid to follow a winding path through said heat exchanging chamber.

37. A fuel reformer according to claim 36 including a plurality of said baffle plates, one of said baffle plates being in close proximity to said outlet apertures and having a central opening through which said gaseous fluid flows in a radially outward direction toward said outlet apertures.

38. A fuel reformer according to claim 32 or 34, wherein said outer shell member includes a sidewall formed with projections that are spaced around the outer shell and that project radially inwardly to engage said sidewall of the primary shell member.

39. A fuel reformer according to any one of claims 32 to 37, wherein there are a plurality of said one or more outlet apertures formed in said primary shell member and said second catalyst comprises a carbon monoxide cleanup catalyst.

40. A fuel reformer according to any one of claims 31 to 37, wherein said second catalyst is a carbon monoxide cleanup catalyst capable of reducing carbon monoxide concentration in said cooled gaseous mixture.

41. A fuel reformer according to claim 40, wherein said carbon monoxide cleanup catalyst further increases hydrogen yield.

42. A method of converting a fuel to a hot gaseous mixture, comprising:
providing a heat exchanging shell apparatus defining a heat

exchanging chamber and having a plurality of heat exchange tubes mounted therein so that each extends through said chamber, said tubes providing passageways for flow of the hot gaseous mixture;

introducing a gaseous fluid into said heat exchanging chamber, passing said gaseous fluid through said chamber, and thereby causing said gaseous fluid to be heated by heat exchange with said hot gaseous mixture flowing through said tubes;

withdrawing the heated gaseous fluid from said chamber and then causing said heated gaseous fluid to be mixed with the fuel to provide an initial mixture of said fuel and said gaseous fluid;

causing said initial mixture to undergo a reaction to produce said hot gaseous mixture; and

passing said hot gaseous mixture through said passageways, thereby partially cooling said hot gaseous mixture to a lower temperature.

43. A method according to claim 42, wherein said fuel comprises a hydrogen-containing fuel and wherein the reaction of the fuel and the gaseous mixture is a catalytic fuel conversion reaction which produces hydrogen in the gaseous mixture.

44. A method according to claim 43, wherein said initial mixture comes into contact with a first catalyst capable of effecting the catalytic fuel conversion reaction, and wherein the gaseous mixture containing hydrogen flows from the first catalyst.

45. A method according to claim 44, wherein the first catalyst comprises an autothermal reformation catalyst.

46. A method according to claim 45, wherein the gaseous fluid contains water and oxygen.

47. A method according to claim 46, wherein said gaseous fluid comprises a mixture of air and steam.

48. A method according to claim 44, wherein the first catalyst comprises a partial oxidation catalyst.

49. A method according to claim 44, wherein the first catalyst comprises a steam reformation catalyst.

50. A method according to claim 44 wherein said hot gaseous mixture passes through said passageways to a second catalyst, said method further comprising:

causing said partially cooled gaseous mixture to come into contact with said second catalyst, thereby reducing a concentration of carbon monoxide in said partially cooled gaseous mixture.

51. A fuel conversion reactor according to claim 50, wherein the second catalyst is a water/gas shift reaction catalyst.

52. A fuel conversion reactor according to claim 50, wherein the second catalyst is a preferential oxidation catalyst.

53. A fuel conversion reactor according to claim 43, wherein said hydrogen-containing fuel is selected from one or more members of the group comprising petroleum fractions, natural gas or components thereof, and alcohols.

54. A fuel conversion reactor according to claim 53, wherein said hydrogen-containing fuel is selected from the group comprising gasoline, kerosene, diesel fuel, naphtha, methane and propane.

55. A method according to claim 42, wherein said heat exchanging shell apparatus includes a primary shell member having two opposite ends and a first tube sheet fixedly mounted in proximity of one of said two ends and a secondary shell member having a first end located adjacent the other of said two ends and a second tube sheet fixedly connected thereto, said plurality of heat exchange tubes extending from said first tube sheet to said second tube

sheet and connected to both tube sheets, and wherein said heated gaseous fluid is withdrawn from said chamber through one or more apertures formed in at least one of said primary shell member and said secondary shell member in the region of said other of said two ends of said primary shell member.

56. A method according to claim 55, wherein said heat exchanging shell apparatus includes an outer shell member which encloses at least a substantial portion of said primary and secondary shell members, a fuel passageway being formed between said outer shell member and said primary shell member and extending longitudinally from a fuel inlet of said outer shell member to said other of the two ends of the primary shell member, and wherein said method includes heating said fuel by causing said fuel to flow along said fuel passageway and thereby providing heat exchange between said fuel and said gaseous fluid passing through said chamber.

57. A method according to claim 55 or 56, wherein said fuel comprises a hydrogen-containing fuel and wherein the reaction of the fuel and the gaseous mixture is a catalytic fuel conversion reaction which produces hydrogen in the gaseous mixture,

wherein said initial mixture comes into contact with a first catalyst capable of effecting the catalytic fuel conversion reaction, and wherein the gaseous mixture containing hydrogen flows from the first catalyst, and

wherein said first catalyst is arranged in said secondary shell member and a second catalyst is arranged in said primary shell member in proximity to said one of said two ends thereof.

58. A method according to any one of claims 55 to 57 wherein said first end of the secondary shell member and said other of the two ends of the primary shell member form a disconnected joint, and wherein the step of passing said hot gaseous mixture through said passageways causes thermal expansion of said heat exchange tubes and a resulting movement of said secondary shell member relative to said primary shell member.

59. A method of converting hydrogen-containing fuel to hydrogen using a

catalytic reaction, said method comprising:

providing an outer shell having first and second ends, said second end being closed, and an inner shell apparatus having two opposite ends, extending into said outer shell at said first end and being joined to said outer shell, a passageway being formed between said outer shell and said inner shell apparatus and extending from an inlet for hydrogen-containing fuel to one of said two ends of said inner shell apparatus;

passing a gaseous fluid through a chamber formed in and by said inner shell apparatus in order to heat said gaseous fluid and then passing said gaseous fluid through one or more apertures formed in a side of inner shell apparatus whereupon the heated gaseous fluid enters said passageway;

simultaneously passing hydrogen-containing fuel through said inlet and said passageway and thereby causing said hydrogen-containing fuel to be initially heated by heat exchange with said heated gaseous fluid and then to be mixed with said heated gaseous fluid so as to provide a mixture of said fuel and said gaseous fluid; and

causing said mixture to come into contact with catalytic material to produce hydrogen by means of a catalytic reaction process.

60. A method according to claim 59, wherein said gaseous fluid contains water and oxygen.

61. A method according to claim 60, wherein said gaseous fluid comprises a mixture of air and steam.

62. A method according to claim 59, wherein said inner shell apparatus comprises a primary inner shell member having two opposite ends and a secondary inner shell member having one end thereof located adjacent one of said two ends of the primary inner shell members, said one or more apertures being formed in at least one of said primary inner shell member and said secondary inner shell member in the region of said one end of the primary inner shell member, a plurality of heat exchange tubes are mounted in said primary inner shell member, and said gaseous fluid is heated by means of heat exchange in said chamber by passing hot reformate through said tubes,

said reformate containing hydrogen and being produced by a catalytic fuel conversion reaction of said mixture of said fuel and said gaseous fluid.

63. A method according to claim 59, wherein said catalytic reaction process includes a first catalytic reaction employing a first catalyst for producing a fuel conversion reaction arranged at said one end of said inner shell apparatus and a second catalytic reaction employing a second catalyst arranged at an opposite end of said inner shell apparatus, said first catalytic reaction producing a reformate which is passed through said chamber by means of heat exchange tubes and which is used to heat said gaseous fluid, and said second catalytic reaction reduces a concentration of carbon monoxide in said reformate.

64. A method according to any one of claims 59 to 63, wherein said catalytic material is divided into a first body of catalytic material capable of producing a fuel conversion reaction and a second body of catalytic material with each body mounted in a respective one of opposite end sections of said inner shell apparatus, said first body producing said reformate and said second body reducing a concentration of carbon monoxide in said reformate.

65. A method according to claim 64, wherein said first body of catalytic material is an autothermal reformation catalyst capable of converting said hydrogen-containing fuel to hydrogen.

66. A method according to claim 64, wherein said second body of catalytic material is a carbon monoxide cleanup catalyst.

67. A method according to claim 62, wherein said one end of said secondary inner shell member and the adjacent end of said primary inner shell member form a disconnected joint and said secondary inner shell member moves relative to said primary shell member due to thermal expansion of said heat exchange tubes as said hot reformate passes through said tubes.

68. A method according to claim 59, wherein the gaseous fluid flows radially outwardly through the one or more apertures where it enters the passageway and is combined with the fuel, said gaseous fluid and fuel being uniformly mixed in a mixing chamber such that the mixture presents a uniform distribution to the catalytic material.

69. A fuel conversion reactor according to claim 1, wherein the fuel and the gaseous fluid are introduced together through the inlet.

70. A fuel conversion reactor according to claim 1 including an outer shell having first and second ends and an outer shell wall extending between said first and second ends, the second end of the outer shell being located proximate the second tube sheet device and being closed by an end cap member, the end cap member having an inlet for said fuel, the inlet communicating with a mixing chamber for mixing the fuel and the gaseous fluid, the mixing chamber being located between the end cap member and the second tube sheet device.

71. In a fuel conversion reactor, a shell-and-tube heat exchanger for heating a gaseous fluid prior to reaction with a fuel and for cooling a gaseous mixture produced by the reaction, said heat exchanger comprising:

(a) a first heat exchanger section comprising:

(i) a first primary shell member having primary and secondary ends and a sidewall extending between said ends and defining a first heat exchanging chamber located within the first shell member;

(ii) a first tube sheet fixedly mounted on said primary shell member in the vicinity of said primary end and sealingly closing said first heat exchanging chamber at one end of the first chamber;

(iii) a second tube sheet device which is separate from said primary shell member and is located in the vicinity of said secondary end, said second tube sheet device forming another end of said first chamber that is opposite said one end of the first chamber; and

(iv) a plurality of heat exchange tubes extending from said first tube sheet to said second tube sheet device and rigidly connected to both the first

tube sheet and the second tube sheet device, said heat exchange tubes providing passageways for said gaseous mixture to flow inside the tubes through said first heat exchanging chamber; and

(v) one or more outlet apertures formed in the region of said secondary end of said primary shell member in order to provide at least one outlet for said gaseous fluid which flows through said first heat exchanging chamber on a shell-side thereof during operation of said fuel conversion reactor; and

(b) a second heat exchanger section comprising:

(i) a second primary shell member having primary and secondary ends and a sidewall extending between said ends and defining a second heat exchanging chamber in communication with the first heat exchanging chamber, the second shell member being concentric with the first shell member with the primary end of the first shell member being located proximate the secondary end of the second shell member;

(ii) a plurality of heat exchanging tubes mounted in the second shell member and communicating with the heat exchange tubes of the first heat exchanger section;

(iii) an inlet in the sidewall of the second shell member for introducing the gaseous fluid into the second heat exchanging chamber;

(iv) one or more outlet apertures formed in the region of the secondary end of the second shell member to provide at least one outlet for the gaseous fluid to flow from the second heat exchanging chamber to the first heat exchanging chamber.

72. A fuel conversion reactor according to claim 71, wherein the first heat exchanger section further comprises one or more inlet apertures formed in the region of the primary end of the first shell member to provide at least one inlet for the gaseous fluid to flow into the first heat exchanging chamber from the second heat exchanging chamber.

73. A fuel conversion reactor according to claim 72, further comprising an outer shell section having first and second ends surrounding the secondary end of the second shell member and the primary end of the first shell member

and forming a passageway for flow of the gaseous fluid from the second heat exchanging chamber to the first heat exchanging chamber, the first and second ends of the outer shell section being rigidly attached to the respective sidewalls of the first and second shell members, said passageway being formed between the outer shell section and the shell members.

74. A fuel conversion reactor according to claim 73, wherein the one or more outlet apertures formed in the region of the secondary end of the second shell member are formed between the first and second shell members.

75. A fuel conversion reactor according to claim 74, wherein the one or more outlet apertures formed in the region of the secondary end of the second shell member comprises a disconnected joint between the first and second shell members.

76. A fuel conversion reactor according to claim 72, wherein the primary end of the first shell member is of a greater diameter than the secondary end of the second shell member and wherein the secondary end of the second shell member is received inside the primary end of the first shell member, and wherein the primary end of the first shell member is rigidly attached to the sidewall of the second shell member such that a passageway for flow of the gaseous fluid from the second to the first heat exchanging chamber is formed between the first and second shell members.

77. A fuel conversion reactor according to claim 76, wherein the one or more inlet apertures comprise a continuous annular gap between the first and second shell members.

78. A fuel conversion reactor according to claim 76, wherein the one or more inlet apertures comprises a disconnected joint formed in the sidewall of the first shell member proximate its primary end.